Financially Optimizing the Investment in Maintenance for Industrial and Military Applications

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Abstract

This paper describes the basis of financial optimization of maintenance resources to address those components that are of the greatest financial risk. The approach is based on industrial applications where the primary concern is the loss of production for profit. The industrial approach is expanded to the military application where the primary concern is the availability for mission with the prudent application of maintenance resources.

Introduction

Many critical industrial plant components are in the aging part of their life cycle. This is because many of the plants in the industrialized world were built during the 50's and 60's. In the aging portion of component life the failure rate is exponential. This creates a need for major predictive maintenance expenditures to maintain reliability.

The major problem in predictive maintenance is choosing which component to repair or replace first and more importantly when to take this action. The Financial Risk Optimization process development began 10 years ago[1]. It was focused on industrial applications where production equipment had reached the aging part of its life cycle. A few of the areas of application to maintenance timing have been:

1) Fossil Power Plants
2) Oil Field Well Head
3) Gas Transmission Lines and Compressor Foundations

These applications have been encouraged because of the lowering of maintenance budgets and the operation of plants beyond their original planned life.

Similar constraints have occurred in the military sector. With this realization the questions was asked, "How can the Financial Risk Optimization process could be applied in the military environment to help present the need for maintenance resources in the military?" That is the subject of this paper.

Industrial Application

[1] Mauney, D. A., "Economic Optimization of Multiple Component Replacement/Inspection in the Power System Environment," Reliability and Risk in Pressure Vessels and Piping, ASME PVP-Vol 251, 1993, Edited by J.H. Phillips, New York, pp 1-16.

In industry the objective is to maximize the savings on the invested maintenance dollar. Net Present Value (NPV), as a decision making criteria, is a way of achieving this "Value Added," objective. NPV also accounts for the cash flow of consequences over the service life of equipment. Maintenance expenditures are investments to receive the benefit of production return in the near, intermediate and long term, or to save money that might be spent if more costly consequences of failure are realized.

Net Present Value puts all expenditures in a common media for communication with the decision maker. Maintenance, together with engineering analysis results, has been difficult to communicate to the decision maker in the past. Concentrating on conversion of maintenance and engineering effects into cash flow and NPV terms allows them to compete with other parts of the organization in a clear manner.

The goal then becomes to:

1) chose implementation of inspect/repair/replace activities that produce positive NPV's, and
2) time the implementation of these inspect/repair/replace activities so that the overall NPV is maximized.

This is the purpose of Financial Risk Optimization for Multiple Components. The resulting prioritized list of activity implementation years is the timing for maximized NPV. The overall NPV is the "Value Added," by the whole optimization process for multiple components.

One of the most important characteristics of the analytical approach to Financial Risk Optimization is that all the elements are within the engineering, maintenance and operations world. Usually financial or decision models include revenues to obtain the NPV. This does not focus on maintenance since maintenance saves money as opposed to making money. This point is very important in allowing the expansion of the industrial process to military applications.

Decision analysis is used to construct an influence diagram (Figure 1) and MS Excel tool model of the corporate financial process in the area of predictive maintenance expenditures and their effect on future unit reliability. Decision analysis is amenable to bridging the gap between engineering analysis, expressed in terms of probability of failure, to financial analysis in the decision making process. Spreadsheet modeling makes the model open and easy to review. Figure 2 demonstrates how this decision model is constrained in an analysis by budget limits, probability of failure safety limits for safety components.

Financial Risk Optimization creates savings by looking at the long range life cycle of the component not just the short range view of the decision. The plan is usually to operate these components for a number of years, therefore, looking at the financial effects over this whole time frame is more realistic.

The short term effects are accounted for by updating the input data and rerunning of the optimization each year. This provides the benefits of a long range view of the service life of the component, but takes account of the short range by implementation of the plan one year at a time.

The systematic approach of modeling and inputting into the prioritization process requires forethought on input information and thoroughness on activity support information. The elements of the optimization model are easy to review because the process highlights them. This aids in the detection of overstated inputs.

The specific elements of the model are:
1) The replacement or repair cost in the maintenance activity of concern,
2) The down time consequences with the activity implemented,
3) Realistic constraints such as annual budget limit, etc., and
4) The downtime consequences if the activity is not implemented.

The replacement or repair cost and the downtime consequences with the activity implemented are the cost associated with initiation of the activity. The downtime consequences, without the activity implementation, are the benefit of performing the activity. The budget limit is that constraint that keeps the model grounded in the real world.

The modeling rationale is that if the activity was not implemented there would be certain downtime, i.e., Do Nothing Different or Base Case Cost. In initiation of the activity, we are taking credit for doing something. The decision is constrained by whether maintenance budget is available for the implementation year of the activity.

Figure 3 illustrates the change in NPV as the activity year is changed. The optimization process becomes the changing of the activity year until the maximum NPV determined. If the model is constrained then an alternate activity year is found that meets all the constraints. Component 1 is a case where the maintenance cost is small relative to the consequential cost. Component 2 is a case when the maintenance cost is large relative to the consequential cost.

If there are multiple items of equipment to have their maintenance activity year optimized then the model is built in the third dimension with a new probability of failure, with and without activity, maintenance activity year and activity cost added for each new activity. The optimization process is then the determination of the combination of maintenance activities years that produces the highest combined NPV and falls within the associated constraints.

Carolina Power & Light Co. in the US used this analysis process on nine critical components on each of nineteen fossil units. This resulted in an estimated greater than fifty million dollar increase in NPV over the existing engineering activity dates.

Military Application

For the military application the industrial model is changed with the focus on mission. Obviously the equipment being maintained must be available a certain amount of time in order to meet its mission. This is reflected in Figure 4 with the addition of the Availability Limit Threshold. So the military application is accomplished with adding a different type of constraint that will over ride value.

Secondly the consequential cost is not as obvious in the military application as in the industrial application. Here of course it is not the loss of product sale. However, it is the fixed and variable cost of bringing the equipment in for unscheduled repair. If the equipment would have remained in service as planned this consequential cost would not have been incurred.

The multiple component optimization would be performed the same way as the constrained industrial model but with the appropriate constraints.

Conclusions

A Financial Risk Optimization maintenance decision analysis model can:

1) be optimized for the timing of the maintenance actions, maximizing the value of the maintenance dollar including military applications,

2) create a link between engineering and the financial decision maker as a result of the common definition for risk and expected value of consequence of failure,

3) allow engineering to compete for resources during times of tight budgets, and

4) provide a balance between the concerns for equipment condition and the financial concerns of investment in maintenance.

Acknowledgement

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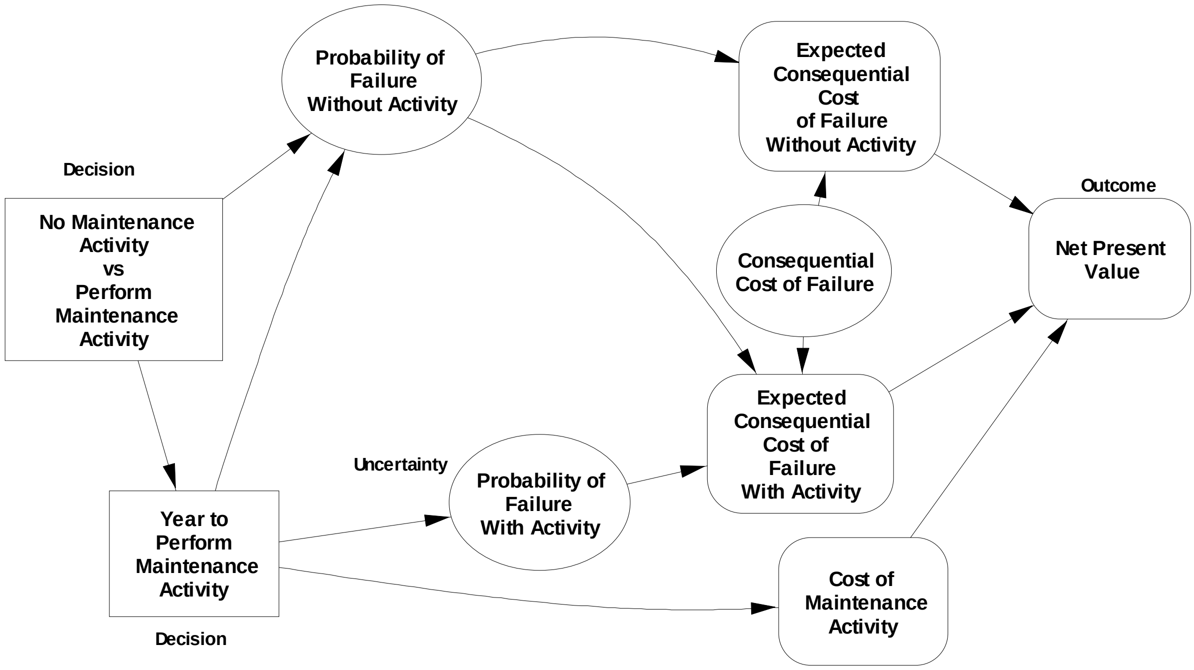

Figure 1. Basic Financial Risk Optimization Decision Analysis Influence Diagram

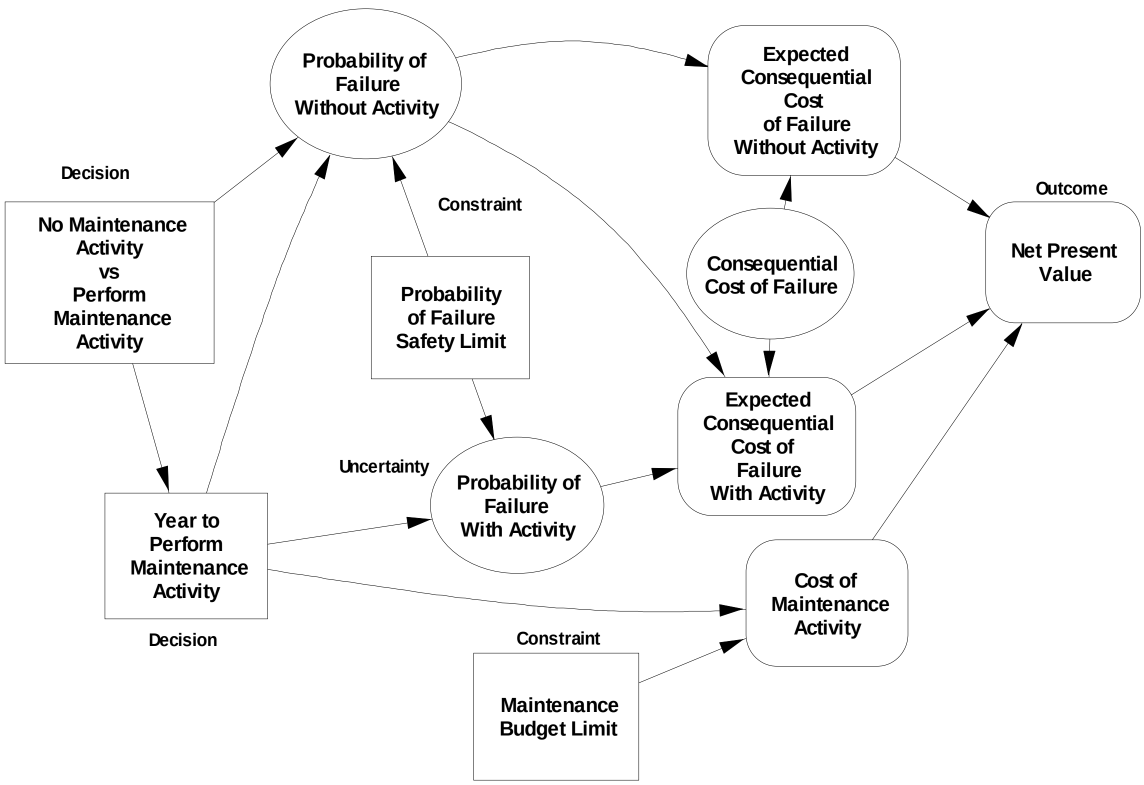

Figure 2. Budget and Probability of Failure Safety Limit Constrained Financial Risk Optimization Process Used in Industrial Applications

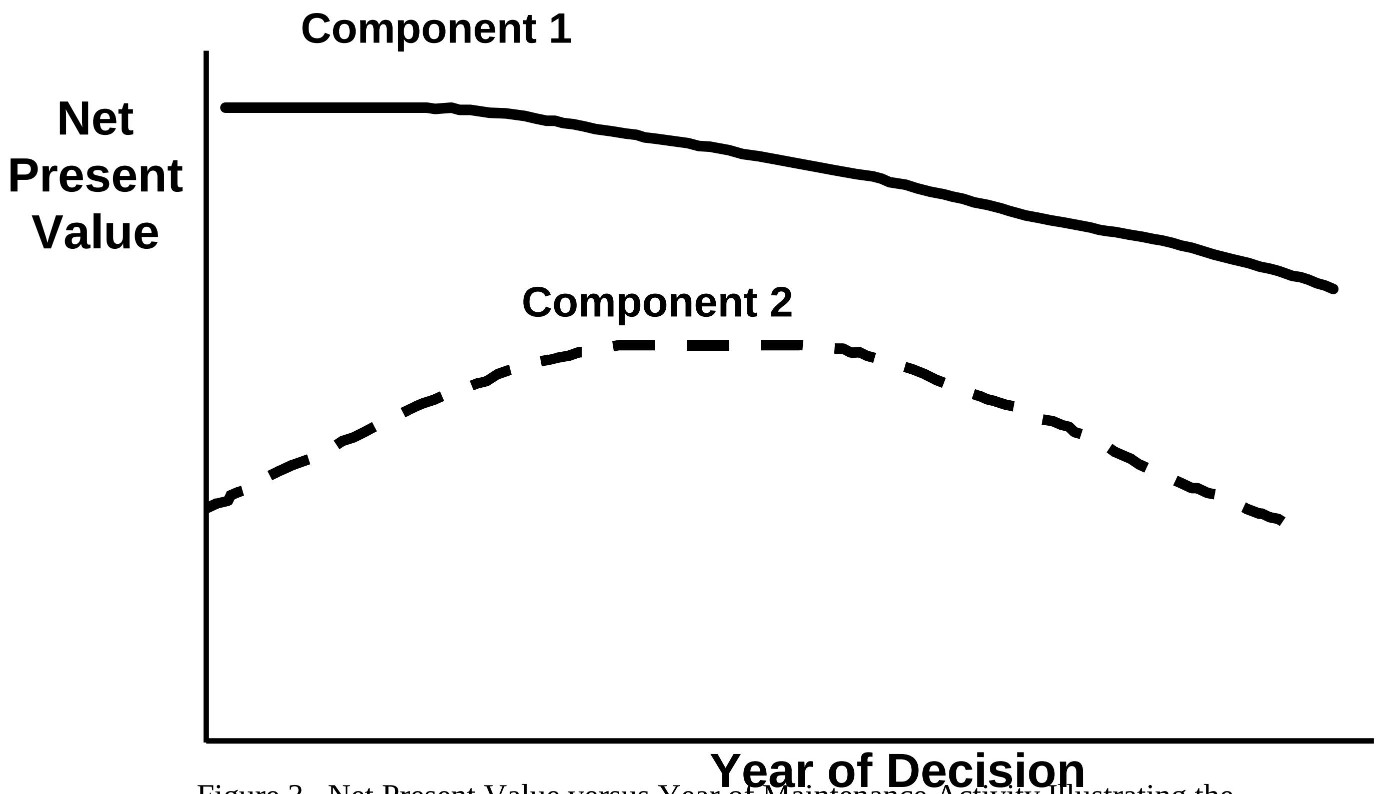

Figure 3. Net Present Value versus Year of Maintenance Activity Illustrating the Importance of Timing of the Maintenance Activity

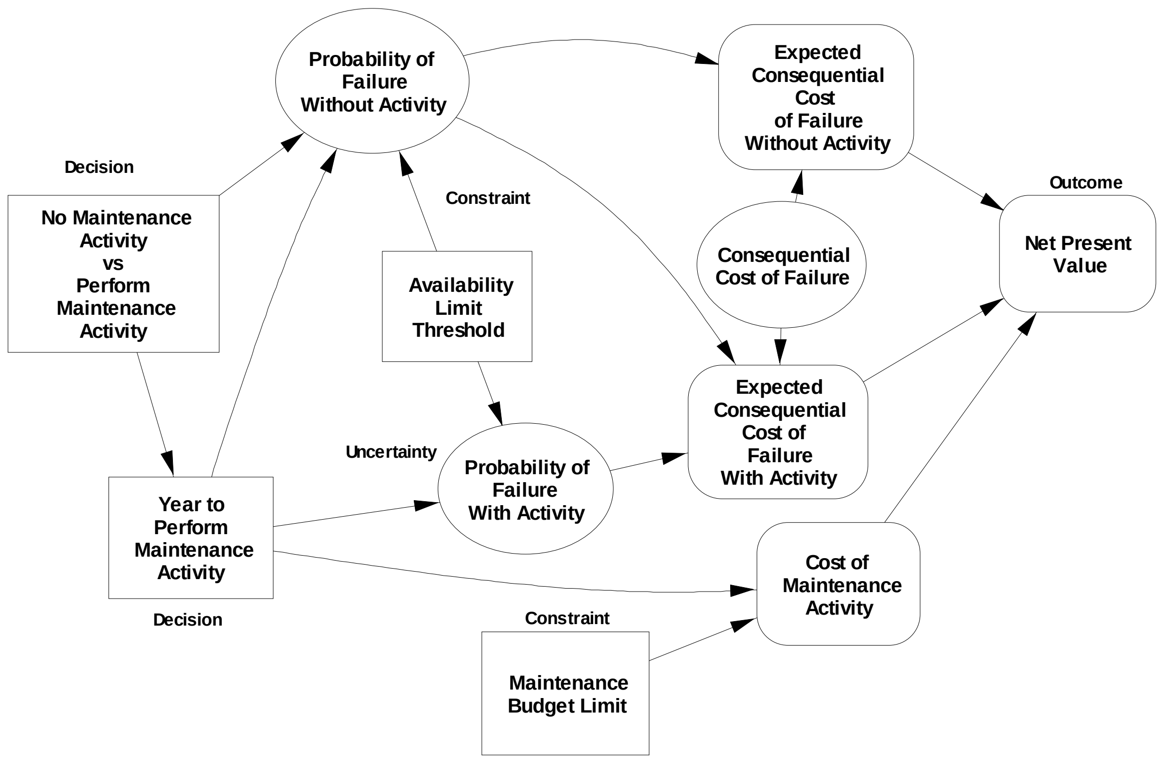

Figure 4. Budget and Probability of Failure Safety Limit Constrained Financial Risk Optimization Process Used in Military Applications